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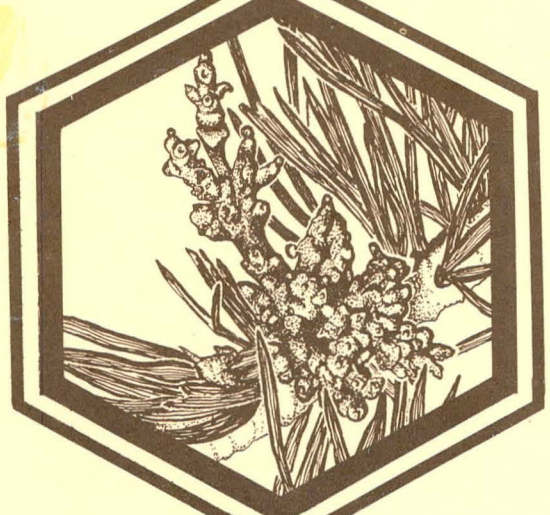

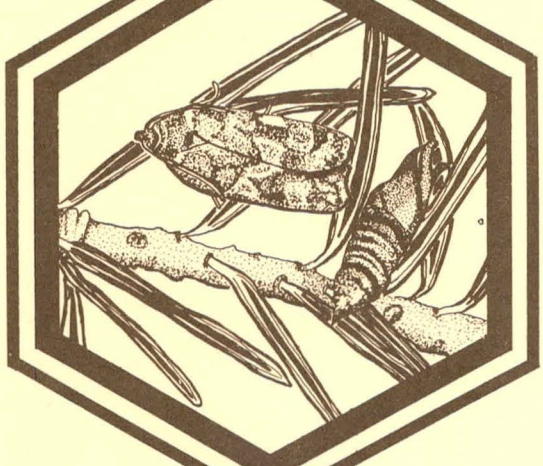

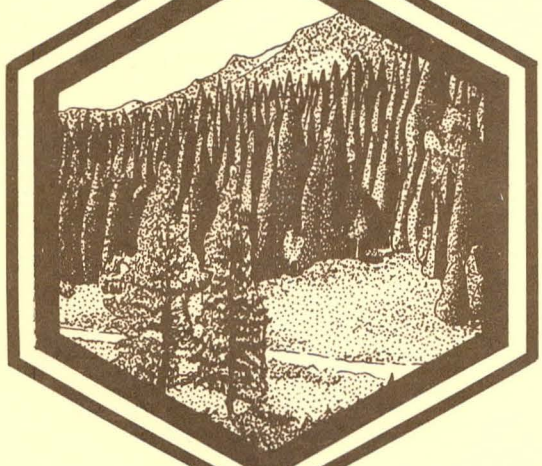

Rpt. No. 79-1

Evaluation of the Marsh Turbo Thrush for Forest Spraying

Methods Application Group
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Report No. 79-1 July 19, 1979

EVALUATION OF THE MARSH TURBO THRUSH FOR FOREST SPRAYING

ERRATUM

Page 13.

Spray Deposit Assessment

Stains on the Kromekote cards were hand-counted and resultant data analyzed by the Automatic Spot Counting and Sizing (ASCAS) program (Young et al. 1977). This program is available at the USDA Computer Center at Fort Collins, Colorado.

Spread factor equations, which represent quantitatively the relationship between the aerodynamic drop size and the stain size it makes on Kromekote cards, for the two tank mixes are as follows:

Thuricide 16B: Aerodynamic Droplet Diameter = $\frac{\text{stain diameter} - 1.30}{1.87}$ (determined by Richard Waite, Forestry Sciences Laboratory, Corvallis, Oregon).

Sevin 4-oil: Aerodynamic Droplet Diameter = 17.8 + 0.365 (stain diameter) - 0.0000333 (stain diameter^2); (determined by Department of Agricultural Engineering, University of California, Davis, California).

Report No. 79-1

3400
November 1978

EVALUATION OF THE MARSH TURBO THRUSH FOR FOREST SPRAYING
Phase 1 - Spray Characterization

John W. Barry, G. Lynne Whyte, Thomas H. Hofacker[1]

ABSTRACT

The Marsh Turbo Thrush aircraft was evaluated at Mesa, Arizona, on February 22-23, 1978, to determine its spray characteristics. Eight successful trials were conducted with Thuricide 16B [R], a commercial compound of Bacillus thuringiensis (B.t.) and three with Sevin 4-oil [R], a commercial product of carbaryl, using Spraying Systems Co. flat fan 8015 and 8020 nozzle tips, respectively. Spray atomization as measured by the volume median diameter (VMD) averaged 156μm for the Thuricide 16B trials and 130μm for the Sevin 4-oil trials. Swath widths ranged from 190' to 340'.

INTRODUCTION

Since 1973, helicopters have been the primary vehicle used by the U.S. Department of Agriculture Forest Service (USFS) to apply insecticides for control of forest defoliators in the western United States. Prior to 1973 fixed-wing aircraft were commonly used to apply insecticides to forests. These aircraft were relatively inexpensive to operate and generally produced acceptable levels of mortality when applying DDT[2] to control forest defoliators. Results, however, were often disappointing when these same aircraft were used to apply insecticides such as Malathion [R] and Zectran [R] which replaced DDT. Poor results indicated that improved application techniques were needed, and that replacement chemicals should be delivered closer to the canopy to increase the probability of an adequate dose reaching the target. The maneuverability of the helicopter was ideally suited for application of insecticides close to the forest canopy over complex forest terrain of the western U.S.. Subsequent tests by the USFS demonstrated the effectiveness in terms of insect control of using helicopters flying close to the canopy. In recent years the cost of aerial application in the forest has risen dramatically. This fact, coupled with helicopter availability problems, has led to increased interest in utilizing fixed-wing agricultural aircraft.

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2 Dichlorodiphenyltrichloroethane.

Piston-powered agricultural aircraft such as the Piper Pawnee, Cessna Ag Wagon, and Grumman Ag-cat have been used on a limited scale to spray forests. The main disadvantages of such aircraft have been low pay load and performance at high altitudes.

Turbine-power conversion units have recently been developed for agricultural spray aircraft such as the Rockwell Thrush Commander and Grumman Ag-cat. The turbine conversion reduced aircraft gross weight, allowing for greater payloads, higher operating speeds, increased maneuverability, and improved performance at higher elevations. Turbine-powered aircraft also require shorter runways than the conventional piston engine models. They have the potential for providing a spray vehicle which may be at least as effective as helicopters in delivering insecticides in a forest environment.

The overall purpose of this project, therefore, was to investigate the suitability of turbine-powered fixed-wing aircraft for application of insecticides to forests. Phase 1 of this report covers spray characteristics. Phase 2, to be published subsequently, will cover performance in a forest environment.

OBJECTIVE

The objective of Phase I was to characterize the spray pattern of a Marsh Turbo Thrush aircraft by droplet spectrum, spray pattern, swath width, and spray volume.

METHODS

A Marsh Turbo Thrush aircraft was characterized by spraying over a sampling line consisting of white Kromekote ^{R} cards. Thirteen trials were conducted on February 22-23, 1978, at Mesa, Arizona (Table 1). Ten trials were run with Thuricide 16B, a commercial formulation of the bacterium Bacillus thuringiensis Berliner (B.t.), produced by Sandoz Inc., and three trials with Sevin 4-oil, a commercial product containing carbaryl, produced by Union Carbide Corp. Only eight of the 10 Thuricide 16B trials were considered successful data trials. The other two were designated no data trials due to a lower application rate.

A sampling line 440' long with white Kromekote cards positioned at 10' intervals was established on a flat area approximately two miles north of Falcon Field, Mesa, Arizona. The line was oriented north-south, normal to the prevailing east-west or west-east winds.

Trials were conducted in the morning between 0710 and 0829 hours, and in the evening between 1800 and 1923 hours. The three Sevin 4-oil trials originally planned for both evening and morning hours were conducted in the evening to minimize effects on bees which may have been foraging in the spray area.

Table 1. Summary, characterization trials, Marsh Turbo Thrush, Mesa, Arizona, February 22-23, 1978.

Trial	Date	Time	Tank Mix	Est. Release Height (ft.)	Flowrate (GPM)	Nozzle Tip Size*	Nozzle Qty.	Nozzle Orientation	Aircraft Speed (mph)	Wind Speed (mph)	Temp. F° (6')	Relative Humidity (%)
2	2-22	1820	Thuricide	50	31.25	8015	21	down	130	<2	65	52
3	2-22	1842	Thuricide	40	31.25	8015	21	down	130	<1	64	48
4	2-23	0647	Thuricide	40	31.25	8015	21	down	130	6.5	50	55
5	2-23	0710	Thuricide	35	31.25	8015	21	down	130	6-8	49	54
6	2-23	0733	Thuricide	40	31.25	8015	21	down	130	7	51	56
7	2-23	0753	Thuricide	50	35.70	8015	24	down	150	7	54	48
8	2-23	0804	Thuricide	50	35.70	8015	24	down	150	6	54	48
9	2-23	0815	Thuricide	50	35.70	8015	24	down	150	6.5	56	50
11	2-23	1845	Sevin	50	18.00	8020	9	down	150	<2	65	54
12	2-23	1912	Sevin	50	18.00	8020	9	down	150	<1	63	48
13	2-23	1923	Sevin	50	18.00	8020	9	down	150	<1	62	47

* Spraying Systems Flat Fan 80 series.

Aircraft and Spray Equipment

The aircraft used on this test was a turbine conversion of the Rockwell Thrush Commander, equipped with a Garrett AiResearch TPE-331 TurboProp (Figure 1). The conversions are produced by Marsh Aviation Company of Mesa, Arizona, and designated as the Marsh Turbo Thrush S2R-T. Performance data are provided in Table 2, and aircraft dimensions are shown in Figures 2, 3, and 4.

The spray system employed a 2" hydraulic root spray pump. The pump is driven by power-take off from the Garrett AiResearch air turbine motor. A schematic of the spray system boom and its position relative to the wing is shown in Figure 5 and 6. The Marsh Turbo Thrush has a 400 gallon tank capacity. Spraying Systems Co. flat fan nozzles with 8015 tips were used with Thuricide 16B, and 8020 tips with Sevin 4-oil. The nozzles were oriented straight down. To reduce the amount of spray material being trapped in the wing tip vortexes, spray nozzles were placed only within the inboard 3/4 of the wing's length. Nozzle location, orientation, and position are shown in Figure 7.

Spray parameters--release height, flowrate, and nozzle number--are given in Table 1. True air speed for trials 2 through 6 was 130 mph, and 150 mph for the other trials. Spray releases, approximately 1500' in length, were made parallel or with the wind and normal to the sampling line.

Meteorology

During testing a high pressure system, characteristic of fair and dry weather, dominated central Arizona. Air movement at the Mesa location was primarily influenced by the typical mountain valley circulation pattern. Winds in the morning were westerly or upslope and in the evening easterly and downslope. Local influence of topography and differentials in surface heating influenced the wind direction and speed during the day.

Testing was conducted during the morning and evening hours when wind direction and speed usually are more predictable and constant. The cooler temperatures and more stable air associated with these periods minimize vertical mixing and rapid dissipation and dilution of the spray.

Meteorological observations were made at the surface (6') level. Observations of wind speed, temperature, and relative humidity are given in Table 1. Although wind direction was not measured quantitatively it was generally normal to the sampling line and parallel to the line of release.

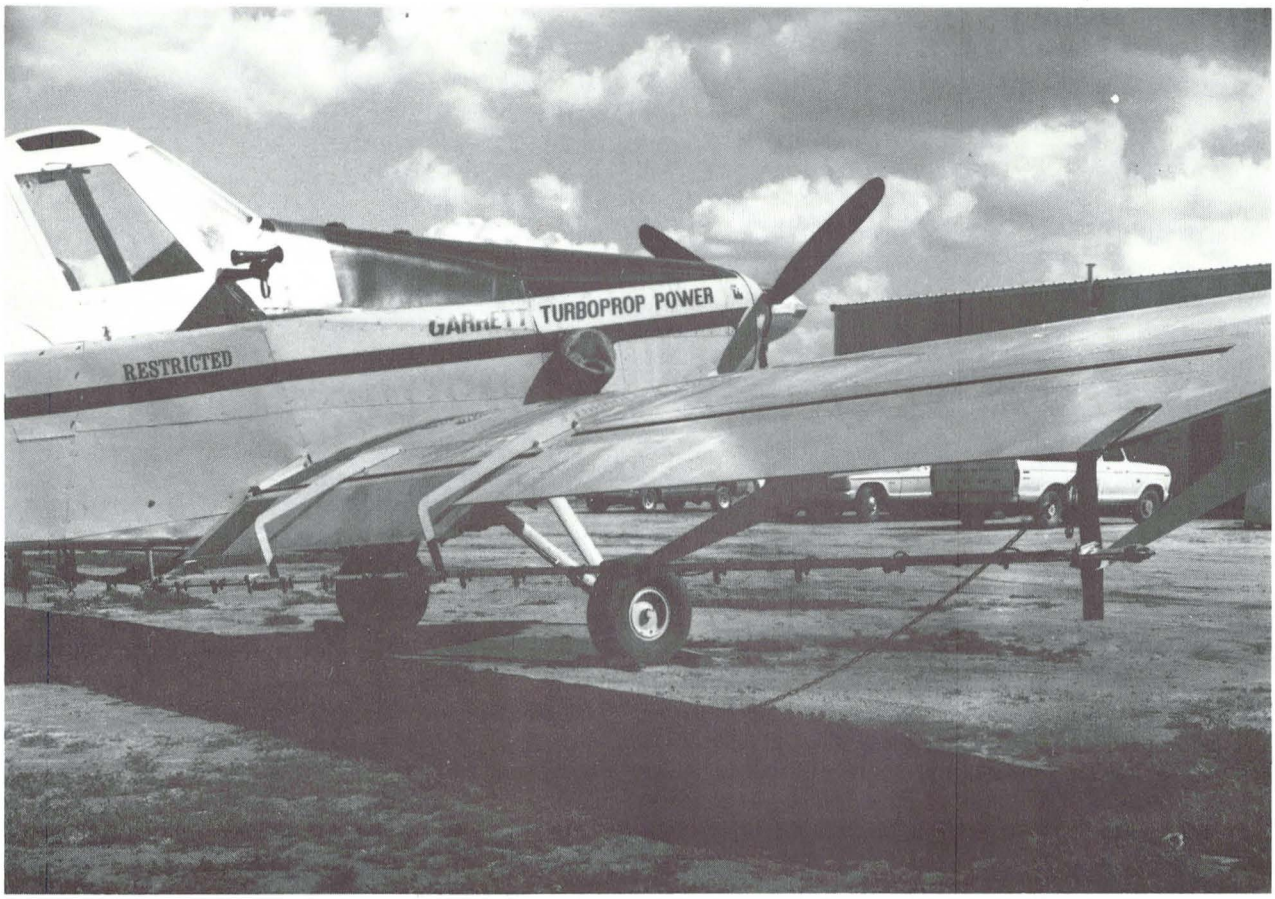

Figure 1. Marsh Turbo Thrush aircraft.

Table 2. Marsh Turbo Thrush S-2R-T Performance Data Sheet*.

Fuel capacity	100 gal.	378.5 liters
Type certified gross wgt.	6000 lbs.	2721.0 kg
Empty weight	3600 lbs.	1632.9 kg
Typical operating weight	7800 lbs.	3537.4 kg
Hopper capacity (53 cu. ft.)	400 gal.	1514 liters
Length	30' 5"	9.296 meters
Height	9' 2"	2.796 meters
Wing span	44' 5"	13.547 meters
Wing area	326.6 squ. ft.	30.047 m^2
Tread	8' 11"	2.719 meters
Service ceiling (gross weight)	25,000 ft.	7620 meters

MAXIMUM SPEED WITH SPRAY EQUIPMENT

Cruise--70% power (sea level)	159 mph	255.9 kph
Ferry range--60% power	500 miles	804.7 km
Working speed--60% power	150 mph	241.4 kph
Stall speed, gross wgt., flaps up	48 mph	77.2 kph
Stall speed, gross wgt., flaps down	44 mph	70.8 kph
Stall speed as usually landed, flaps up	45 mph	72.4 kph
Stall speed as usually landed, flaps down	43 mph	69.1 kph
Sea level rate of climb (gross wgt.)	3000 fpm	914.4 mpm
Fuel consumption	20-40 gph	78 lph
Take off roll	600 ft.	182 meters
--with 400 gal. insecticide/100 gal. fuel--		
Landing distance	300 ft.	91 meters

Cruise 50% power, 10,000 ft., density altitude 171 mph ground speed
Instantaneous power response--rugged fixed shaft engine
Engine braking--ground or in air
Increased propeller clearance
Low engine aerodynamic drag
AiResearch world wide product support

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* Data provided by Floyd Stilwell, President, Marsh Aviation, Mesa, Arizona.

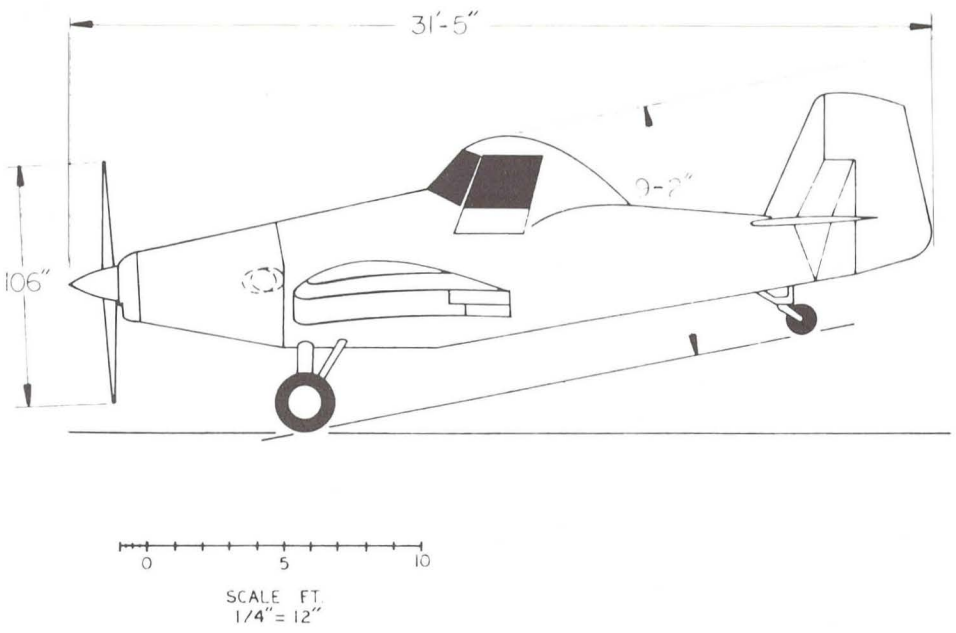

Figure 2. Dimensions of Marsh Turbo Thrush, side view.

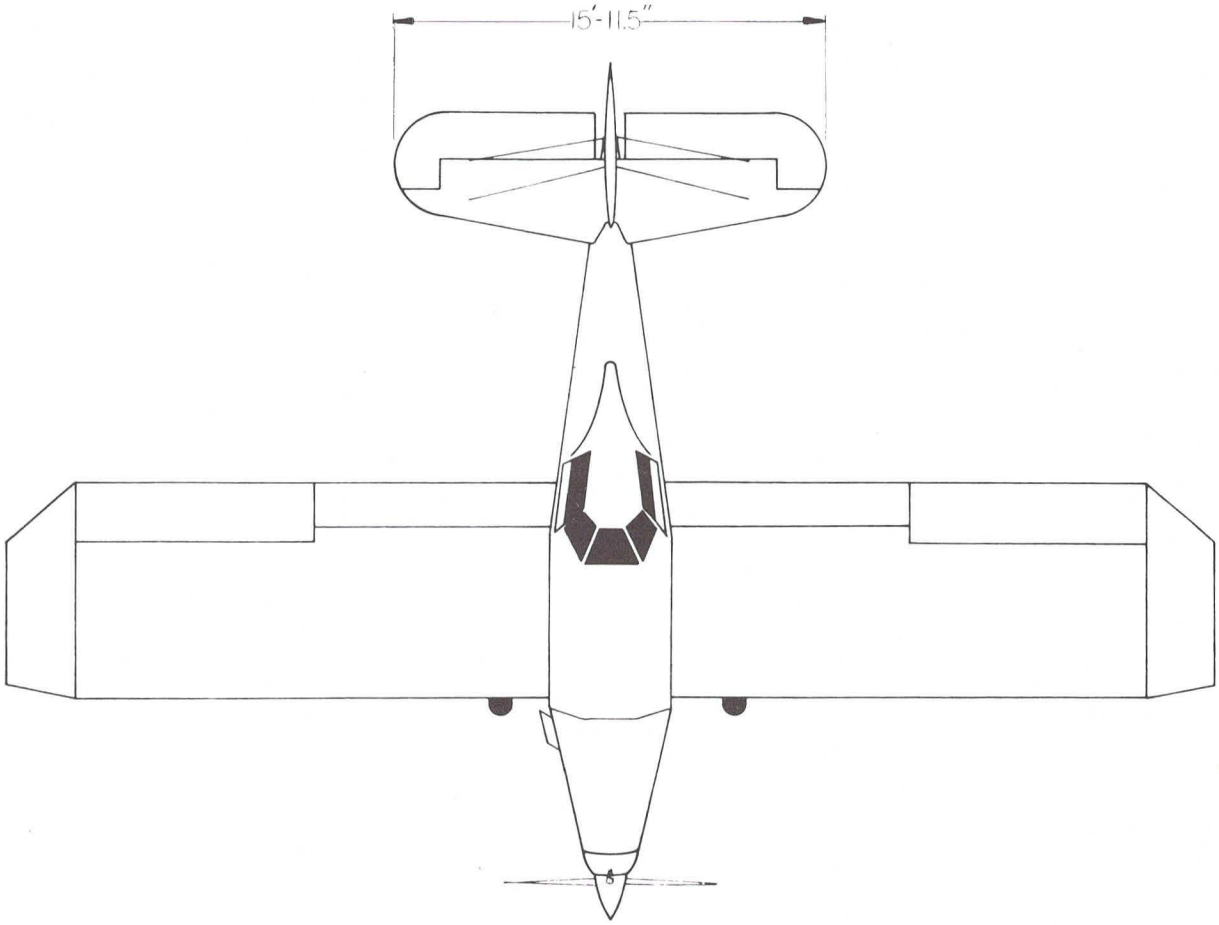

Figure 3. Dimensions of Marsh Turbo Thrush, top view.

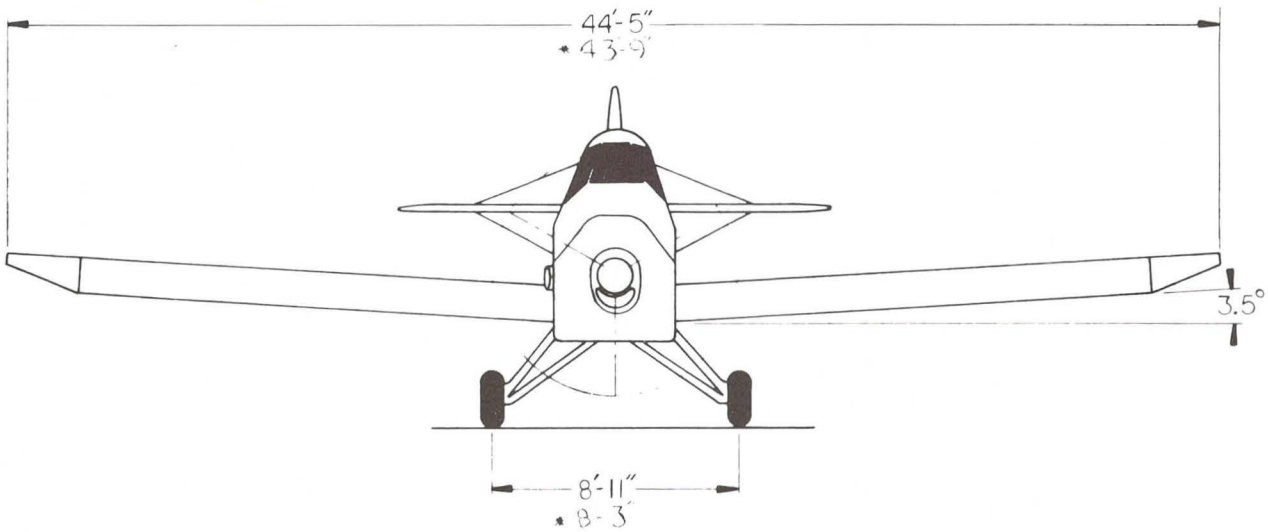

Figure 4. Dimensions of Marsh Turbo Thrush, front view.

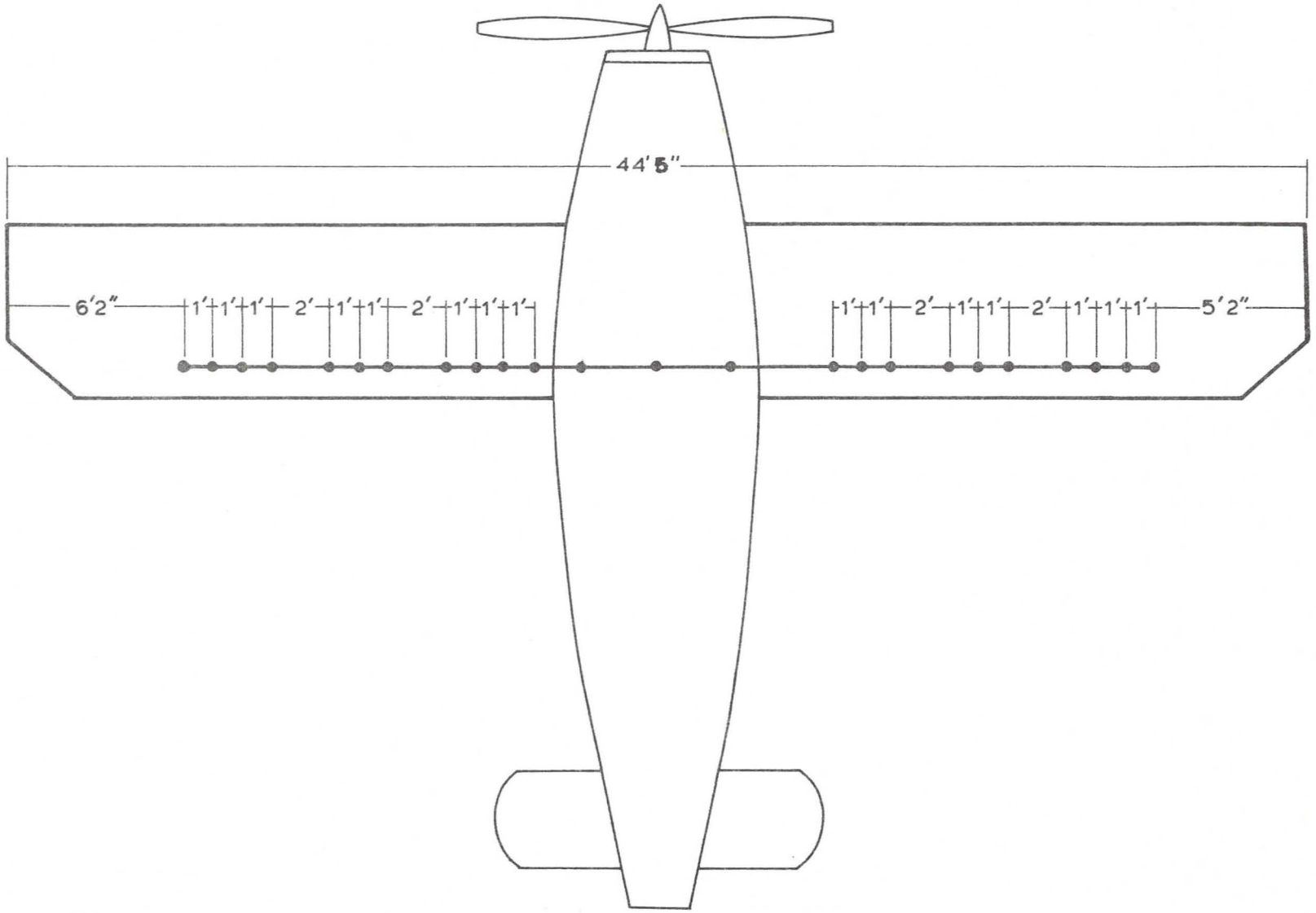

Figure 5. Positioning of Spraying Systems Co. 8015 nozzles for Thuricide 16B trials.

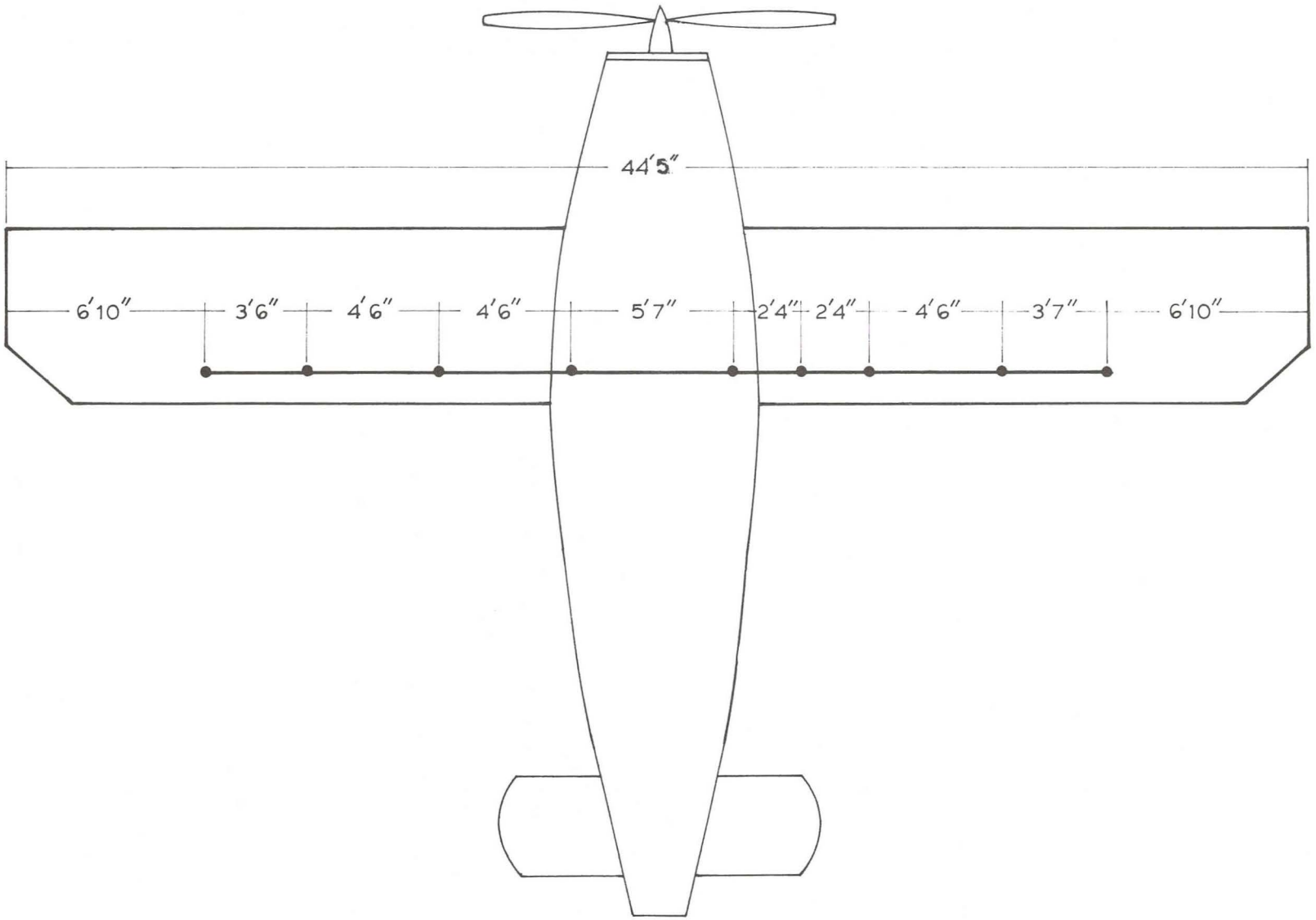

Figure 6. Positioning of Spraying Systems Co. 8020 nozzles for Sevin 4-oil trials.

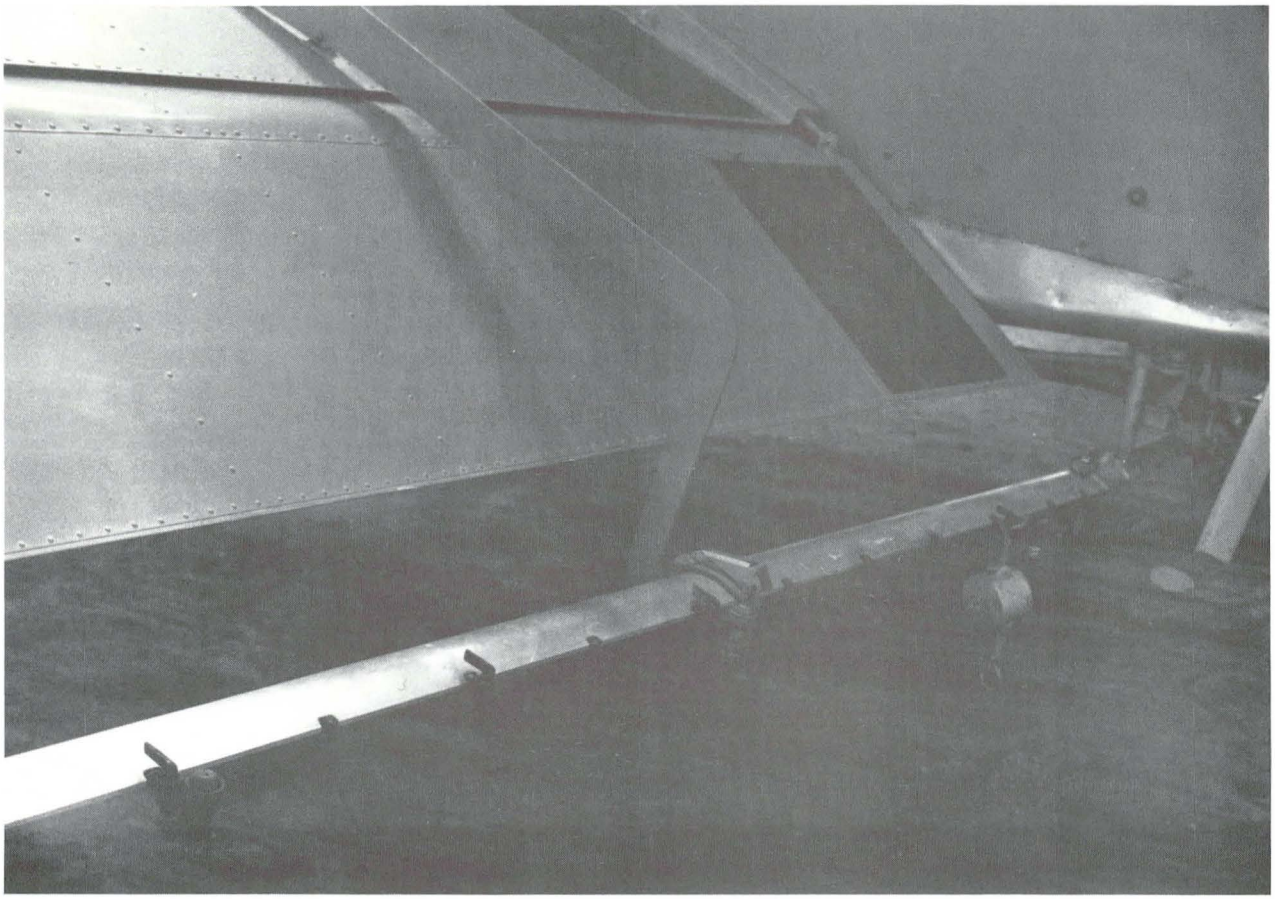

Figure 7. Marsh Turbo Thrush, spray boom and nozzle placement.

Spray Formulation/Tank Mix

The insecticide tank mixes consisted of the following:

Bacillus thuringiensis: Thuricide 16B mixed 50% Thuricide + 50% water and 0.2% by volume of Rhodamine B extra S dye or 2 lb. of dye per 100 gallons of tank mix.

Carbaryl: 50% Sevin 4-oil + 48% No. 2 fuel oil + 2% by volume of Automate Red dye.

Fifty gallons of each tank mix was prepared immediately prior to application.

Spray Deposit Assessment

Stains on the Kromekote cards were hand-counted and resultant data analyzed by the Automatic Spot Counting and Sizing (ASCAS) program (Young et al. 1977). This program is available at the USDA Computer Center at Fort Collins, Colorado.

Spread factor equations, which represent quantitatively the relationship between the aerodynamic drop size and the stain size it makes on Kromekote cards, for the two tank mixes are as follows:

Thuricide 16B: Aerodynamic drop size = 1.87 (stain size) + 1.30 (determined by Richard Waite, Forestry Sciences Laboratory, Corvallis, Oregon).

Sevin 4-oil: Aerodynamic drop size = 17.8 + 0.365 (stain size) 0.0000333 (stain size^2); (determined by Department of Agricultural Engineering, University of California, Davis, California).

Calibration

The Marsh Turbo Thrush was calibrated to apply one gallon/acre of the Thuricide 16B tank mix and ½ gallon/acre of the Sevin 4-oil tank mix. The basic equation used to calibrate was:

(1) $$\text{acres/minute} = \frac{2 \times \text{mph} \times \text{swath width (ft.)}}{1000}$$

(2) spray volume/minute = acres/minute x desired total spray volume/acre (oz).

where:

Aircraft speed	130 and 150 mph
Swath width	120'

Nozzle flowrate

Spraying Systems Co. TeeJet ® Flat Fan tips

8015	1.5 gallons/minute (Thuricide 16B)
8020	2 gallons/minute (Sevin 4-oil)

Boom pressure was 40 pounds/in.^{2} gage (psig).

RESULTS

Data on swath width, droplet density, droplet size, and spray volume were obtained for both the Thuricide 16B and Sevin 4-oil trials. A summary is given in Table 3.

Thuricide 16B Trials

Trials 1 through 10 were the Thuricide 16B trials. On Trial 1 the spray system was not up to pressure, and on Trial 10 the aircraft ran out of spray material before the end of the spray run. Therefore, only data from trials 2 through 9 were analyzed. Swath width, a linear area normal to the aircraft path receiving at least 10 drops/cm^2, ranged from 150' to 340', even though the Marsh Turbo Thrush was calibrated for a 120' swath width. Droplet size as expressed by volume median diameter (VMD) ranged from 120 to 190 μm, with the higher VMD's associated with the lower speed trials (see Tables 1 and 3). Droplet density averaged over the calibrated swath width (120') ranged from 29 to 65 drops/cm^2 of surface area (Table 4). Spray volume recoveries on the ground as a function of the amount sprayed ranged from 8 to 31%.

Sevin 4-oil Trials

Trials 11 through 13 were conducted during a single evening between 1845 and 1923 hours. Atmospheric conditions were similar on these three trials. Averages of the spray deposit recoveries for the three trials were: swath width 240'; droplet density 40 drops/cm^2; VMD 130μm; and spray volume recoveries 36% of the volume sprayed (Table 5).

Field Determination of VMD

The VMD was determined in the field for each spray run (Dumbauld and Rafferty 1977). Field VMD determinations and the VMD determined mathematically by the ASCAS program were compared (Table 6). There was only a 3μm difference between the averages of the field method and the ASCAS method. This indicated that field methods provide a reliable estimate of actual VMD.

Swath width, recovery of spray volume, and droplet density data are given in Tables 7 and 8, and diagrams of the recovery along the sampling line are shown in Figures 8 through 18.

Table 3. Summary of spray deposit recovery, swath width, drops/cm^2, and volume median diameter (VMD).

Trial	Time	Insecticide	Recovery* Mass G/A	Recovery* Mass (%)	Swath Width	Drops/cm^2	VMD (μm)
2	1820	Thuricide	.124	12	250	32	156
3	1842	Thuricide	.0827	8	230	29	148
4	0647	Thuricide	.237	24	150	39	167
5	0710	Thuricide	.2263	23	200	52	190
6	0733	Thuricide	.3125	31	160	37	189
7	0753	Thuricide	.078	8	190	45	120
8	0804	Thuricide	.076	8	340	40	130
9	0815	Thuricide	.131	13	200	65	144
11	1845	Sevin	.1527	31	230	34	133
12	1912	Sevin	.1777	36	230	45	125
13	1923	Sevin	.1998	40	260	40	133

* Recovery is expressed as a function of application rate (1 gallon/acre for Thuricide 16B, and .5 gallon/acre for Sevin 4-oil) and amount collected or recovered on grid.

Table 4. Drop distribution by %, Thuricide 16B tank mix, Marsh Turbo Thrush characterization, Flat Fan 8015 nozzle tips, Mesa Arizona, February 22-23, 1978.

Drop Diameter Category (μm)	TRIALS							
	2	3	4	5	6	7	8	9
≤ 26	6.4	8.8	6.3	5.7	5.1	8.7	10.3	14.1
< 52.8	58.5	65.3	42.3	61.5	49.2	71.1	65.7	62.6
< 106.3	24.7	17.1	24.7	18.5	22.3	14.9	16.7	16.4
< 159.7	7.2	6.4	19.1	8.9	14.7	4.4	5.6	5.3
< 213.2	1.9	1.4	4.9	2.9	5.2	6.0	1.5	1.4
< 266.7	1.1	1.0	2.1	2.1	2.9	0.3	0.2	0.3
< 320.2	0.2	0	0.4	0.3	0.6	0	0	0
< 373.6	0	0	0	0	0	0	0	0
< 427.1	0	0	0	0	0	0	0	0
< 480.6	0	0	0	0	0	0	0	0

Table 5. Drop size distribution by %, Sevin 4-oil tank mix, Marsh Turbo Thrush characterization, Flat Fan 8020 nozzle tips, Mesa, Arizona, February 23, 1978.

Drop Diameter Category (μm)	TRIALS		
	11	12	13
≤ 36	7.0	8.2	5.1
< 54	36.2	33.9	28.3
< 89.5	28.5	28.2	25.5
< 124.3	16.9	19.2	25.4
< 158.5	7.6	7.3	10.8
< 192	3.1	3.0	4.2
< 224.8	0.7	0.1	0.6
< 257	0	0	0
< 288.5	0	0	0

Table 6. Comparison of volume median diameter (μm) by trial, between the rapid field method using "D-Max" and the ASCAS method. Mesa, Arizona, February 22-23, 1978.

Trial	Insecticide	VMD (μm)	
		Field Method	ASCAS
2	Thuricide	171	156
3	Thuricide	149	148
4	Thuricide	149	167
5	Thuricide	149	190
6	Thuricide	160	189
7	Thuricide	149	120
8	Thuricide	181	130
9	Thuricide	149	144
11	Sevin	140	133
12	Sevin	140	125
13	Sevin	140	133
Average		152	149

Table 7. Thuricide 16B trials, deposit recoveries of gallons/acre (g/a) and drops/cm^2 (drops) of surface area by sample position. Marsh Turbo Thrush, Mesa, Arizona, February 22-23, 1978.

Position No.	TRIALS															
	2		3		4		5		6		7		8		9	
10' Spacings	g/a	drops	g/a	drops	g/a	drops	g/a	drops	g/a	drops	g/a	drops	g/a	drops	g/a	drops
1						3		6	.01	16	.04	39	.05	50		
2					.01	5	.01	7	.02	19	.03	37	0	6	0	4
3					.01	6	.01	8	.03	29	.02	36	.01	10	0	3
4					0	7	.01	8	.08	30	.01	35	.01	13	0	5
5					.01	7	0	8	.07	35	.02	34	.03	28	.02	23
6					.04	12	.01	14	.13	44	.02	35	.02	26	.01	26
7					.05	17	.01	14	.19	45	.02	35	.03	26	.16	9
8					.05	17	.02	16	.24	56	.02	36	.01	25	.13	23
9					.06	21	.02	20	.28	56	.02	35	.07	27	.37	23
10					.06	22	.02	21	.36	59	.02	53	.07	26	.33	23
11					.16	23	.06	39	.49	58	.03	57	.07	41	.36	66
12					.2	31	.04	36	.73	53	.04	62	.06	40	.13	116
13					.16	36	.14	48	.54	34	.04	51	.13	57	.02	110
14					.47	47	.08	51	.54	35	.11	52	.19	58	.04	97
15					.31	43	.61	60	.34	26	.2	57	.06	34	.01	84
16	.43	18			.55	46	.59	61	.53	30	.13	50	.06	36		111
17	.11	16	.04	1	.62	72	.38	62	.38	8	.16	48	.16	61		89
18	.16	39	.1	20	.49	70	.38	63			.15	52	.11	64		81
19	.28	42	.32	38	.37	57	.63	52			.12	50	.32	110		96
20	.39	56	.19	33	.63	57	.45	113			.21	41	.59	121		103
21	.17	56	.12	34	.67	55	.41	121			.2	8	.46	117		67
22	.11	33	.08	42			1.33	133					.38	58		64
23	.14	35	.20	29			.89	117					.04	30		44
24	.24	45	.09	27			.35	99					.03	31		30
25	.14	40	.07	26			.03	27					.02	31		29
26	.22	39	.16	29			.01	22					.03	31		33
27	.16	30	.08	32			0	5					.02	30		26
28	.16	29	.12	36			0	3					.02	29		16
29	.08	33	.07	28			0	3					.01	28		8
30	.1	40	.07	27									.01	32		
31	.06	38	.07	26									.01	19		
32	.05	37	.05	27									.01	24		
33	.03	34	.05	26									.01	11		
34	.04	31	.02	21									0	9		
35	.03	27	.02	21									.01	19		
36	.03	27	.05	21									0	5		
37	.02	28	.02	20									0	7		
38	.03	22	.01	31									0	7		
39	.01	20	.02	34									0	6		
40	.01	13	.02	37									0	5		
41	.01	10	.01	36									0	5		

Table 8. Sevin 4-oil trials, deposit recoveries of gallons/acre (g/a) and drops/cm^2 (drops) of surface area by sample position, Marsh Turbo Thrush, Mesa, Arizona, February 22-23, 1978.

Position No. 20' Spacings	TRIALS 11 g/a	11 drops	12 g/a	12 drops	13 g/a	13 drops
1	.02	16				
2	.02	15				
3	.04	16				
4	.06	19				
5	.12	29				
6	.06	27				
7	.13	30			0	4
8	.08	26			0	6
9	.1	31			.01	8
10	.09	32			.01	11
11	.16	34			.01	13
12	.15	30			.03	22
13	.12	34			.04	26
14	.1	35			.09	30
15	.14	54			.14	40
16	.14	52	0	2	.12	38
17	.19	57	.01	4	.53	60
18	.3	45	.11	20	.45	60
19	.22	42	.33	31	.35	59
20	.15	42	.32	38	.25	55
21	.2	39	.3	51	.73	104
22	.18	40	.36	58	.94	105
23	.33	41	.28	61	.97	105
24	.67	40	.14	22	.25	29
25			.78	117	.02	7
26			.34	106	.02	4
27			.82	127	.31	43
28			.57	111	.29	60
29			.12	57	.13	27
30			.06	37	.04	19
31			.05	35	.02	23
32			.04	33	.01	23
33			.03	34	.01	11
34			.03	29	0	6
35			.02	26		
36			.01	26		
37			.01	18		
38			.01	18		
39			.01	15		
40			.01	11		
41			.01	14		

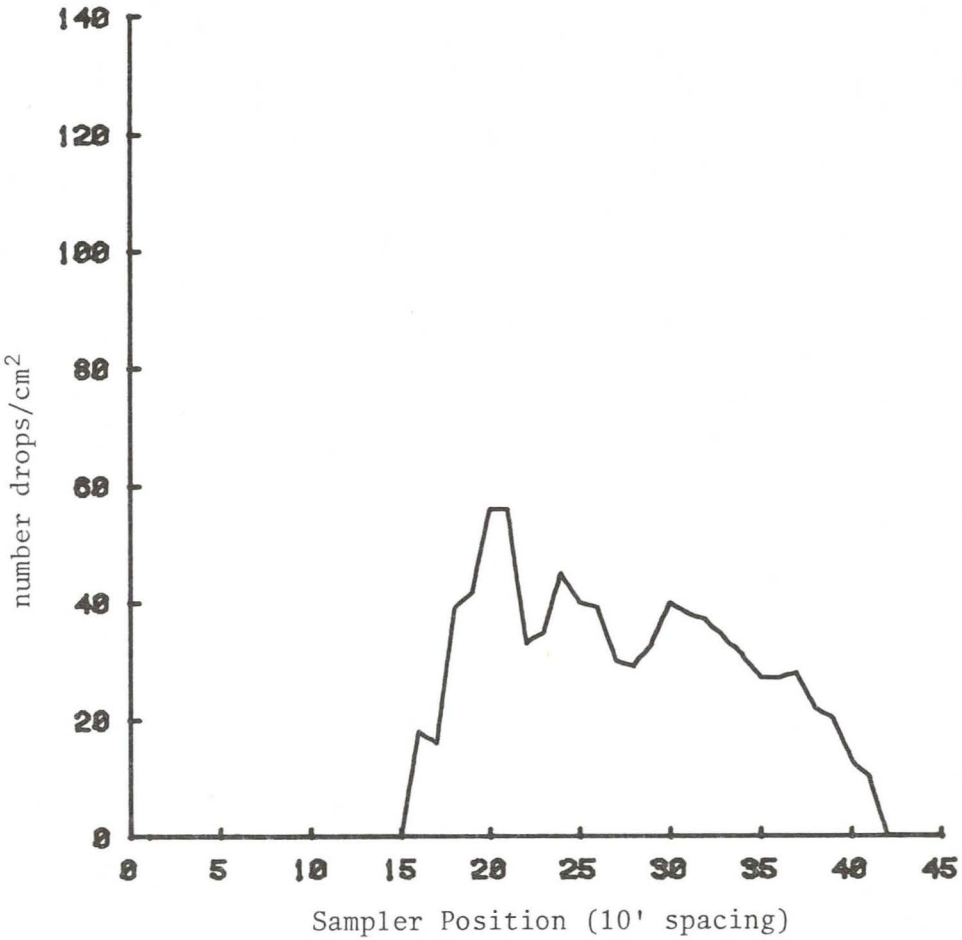

Figure 8. Trial 2, Thuricide 16B, droplet density recovered along sampling line perpendicular to spray release line.

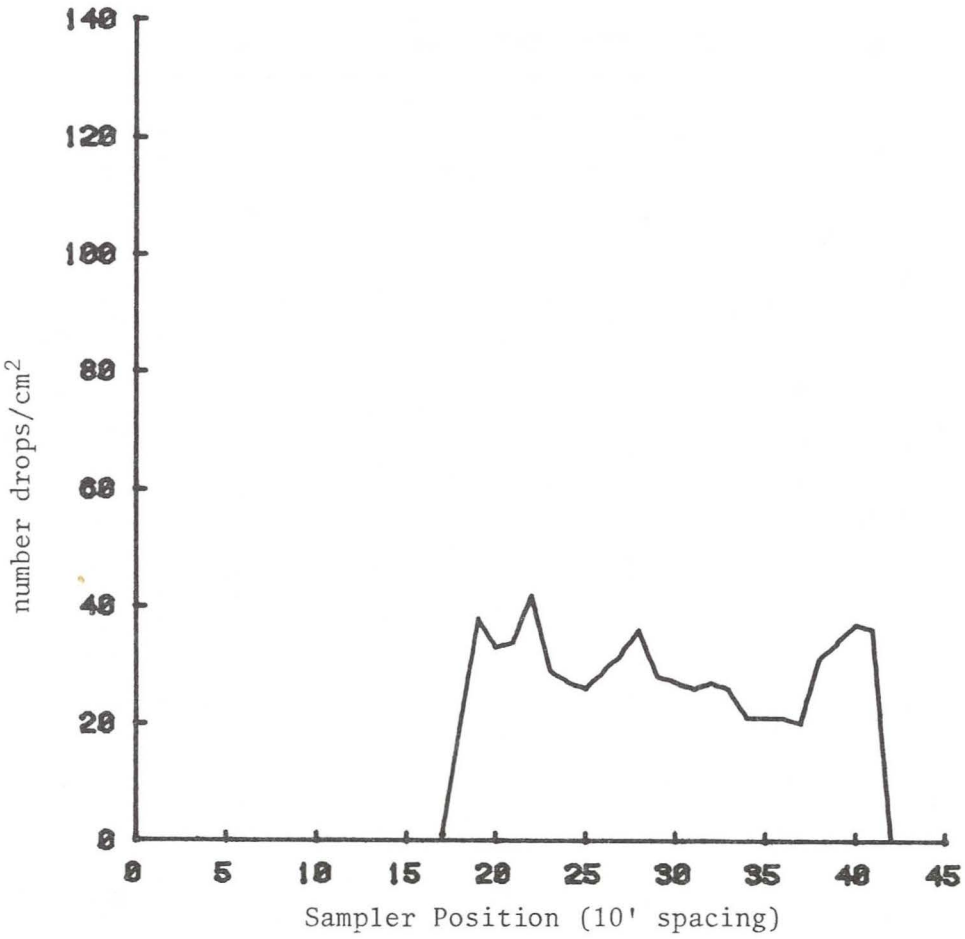

Figure 9. Trial 3, Thuricide 16B, droplet density recovered along sampling line perpendicular to spray release line.

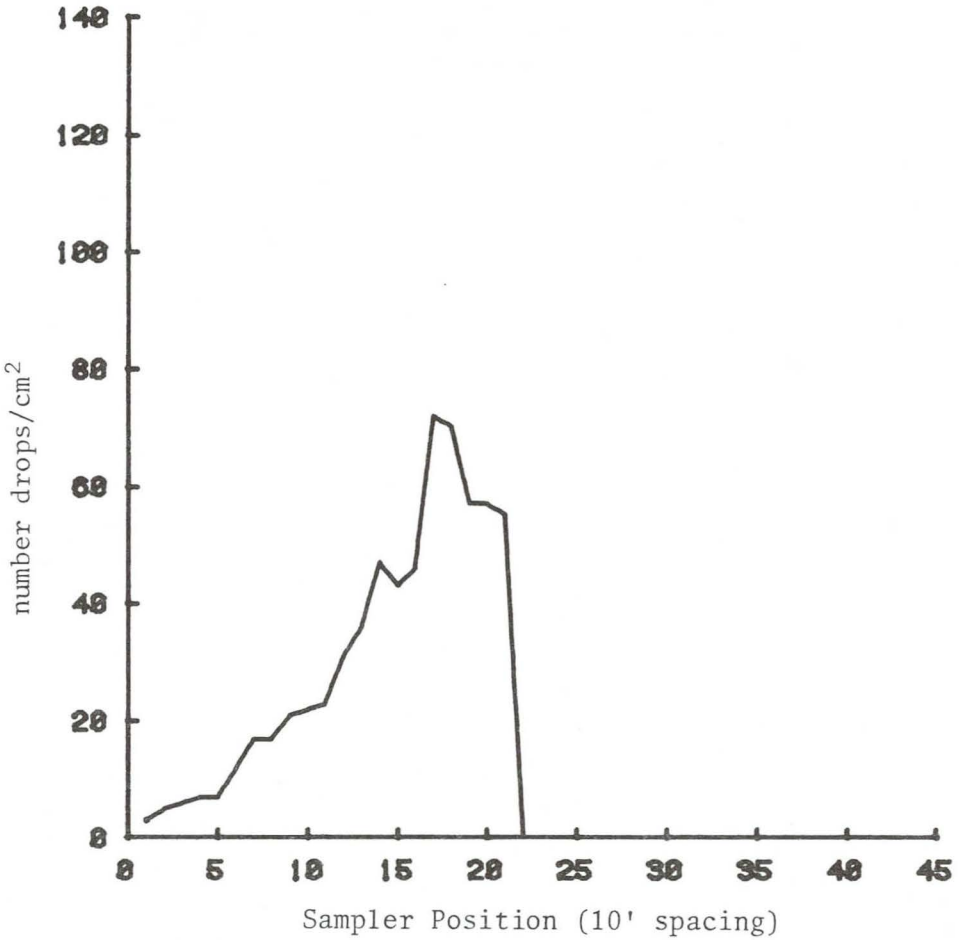

Figure 10. Trial 4, Thuricide 16B, droplet density recovered along sampling line perpendicular to spray release line.

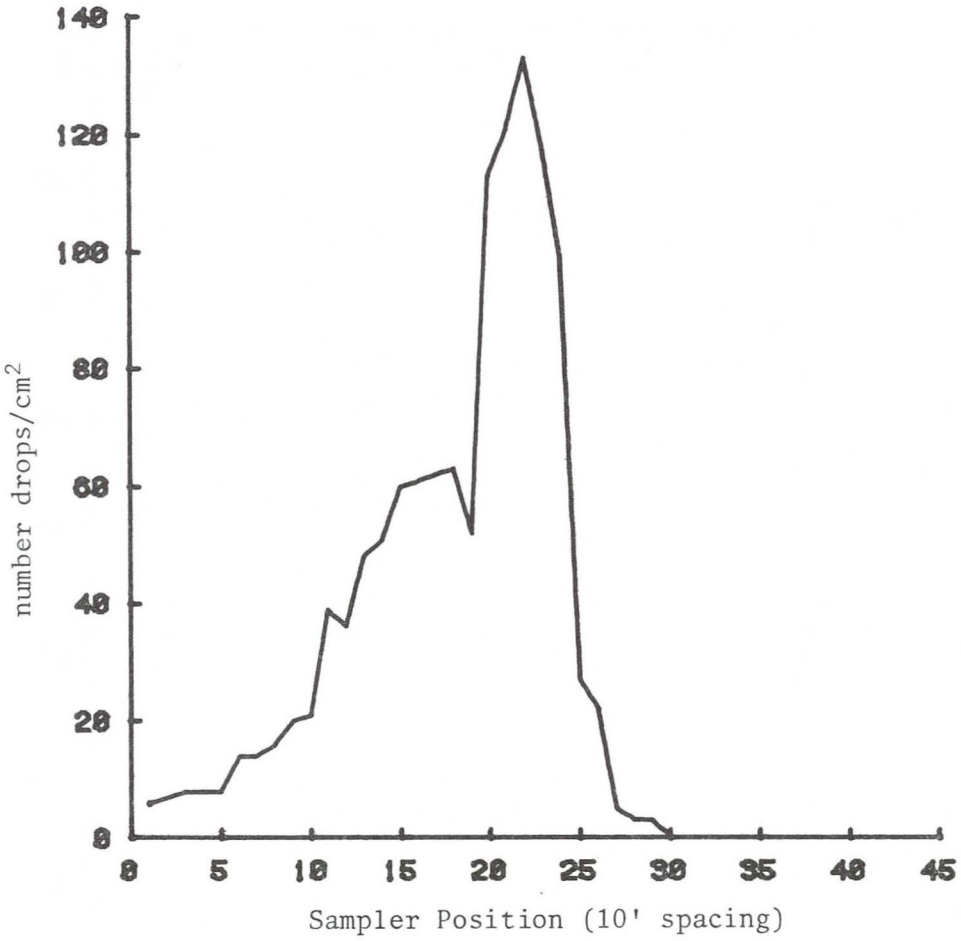

Figure 11. Trial 5, Thuricide 16B, droplet density recovered along sampling line perpendicular to spray release line.

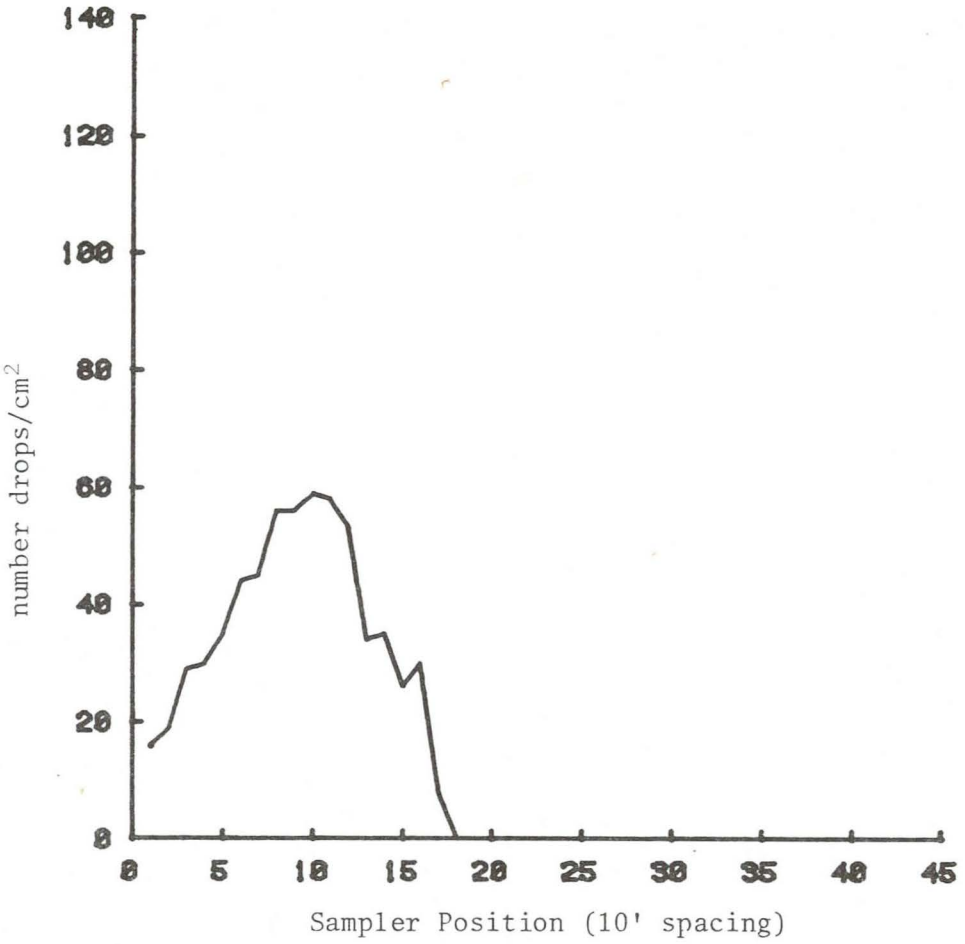

Figure 12. Trial 6, Thuricide 16B, droplet density recovered along sampling line perpendicular to spray release line.

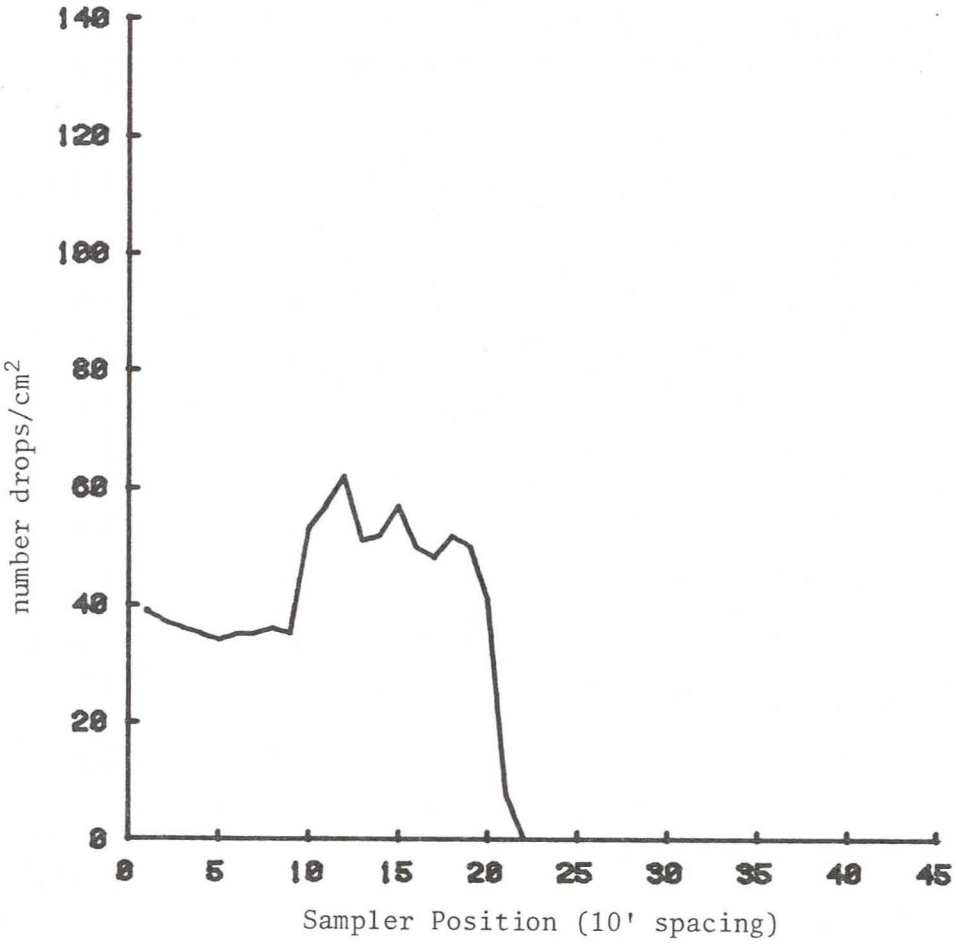

Figure 13. Trial 7, Thuricide 16B, droplet density recovered along sampling line perpendicular to spray release line.

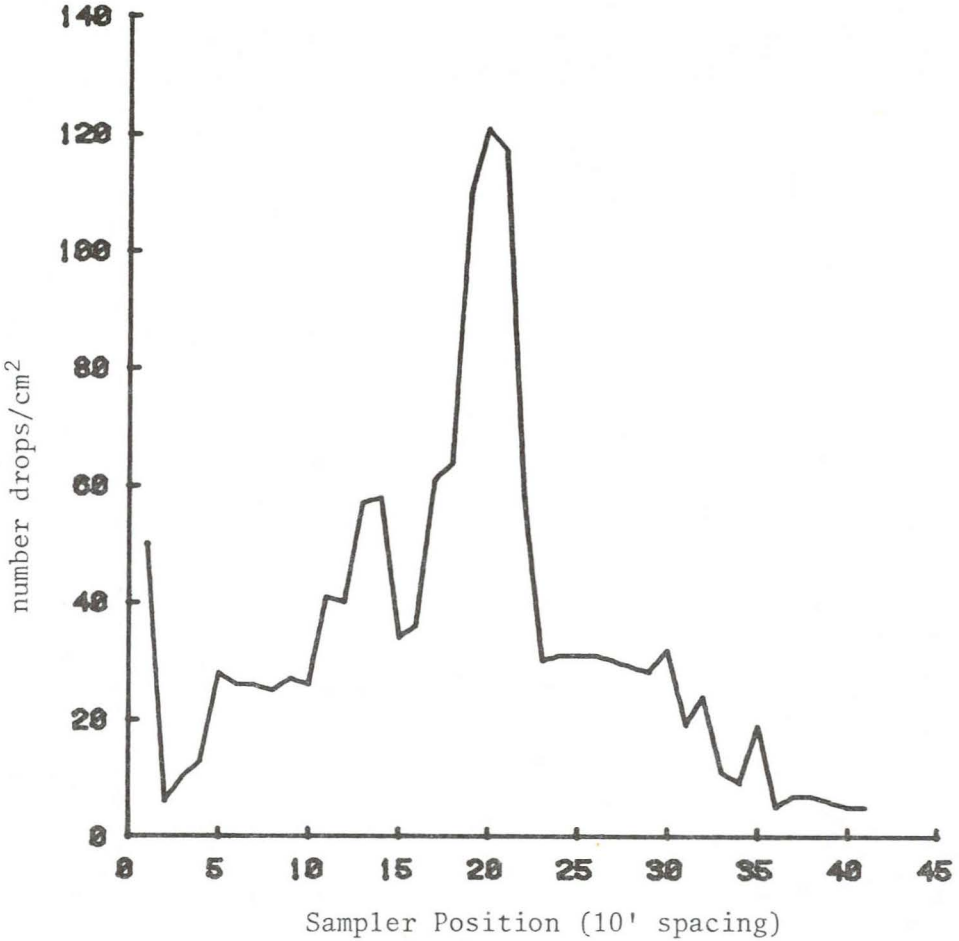

Figure 14. Trial 8, Thuricide 16B, droplet density recovered along sampling line perpendicular to spray release line.

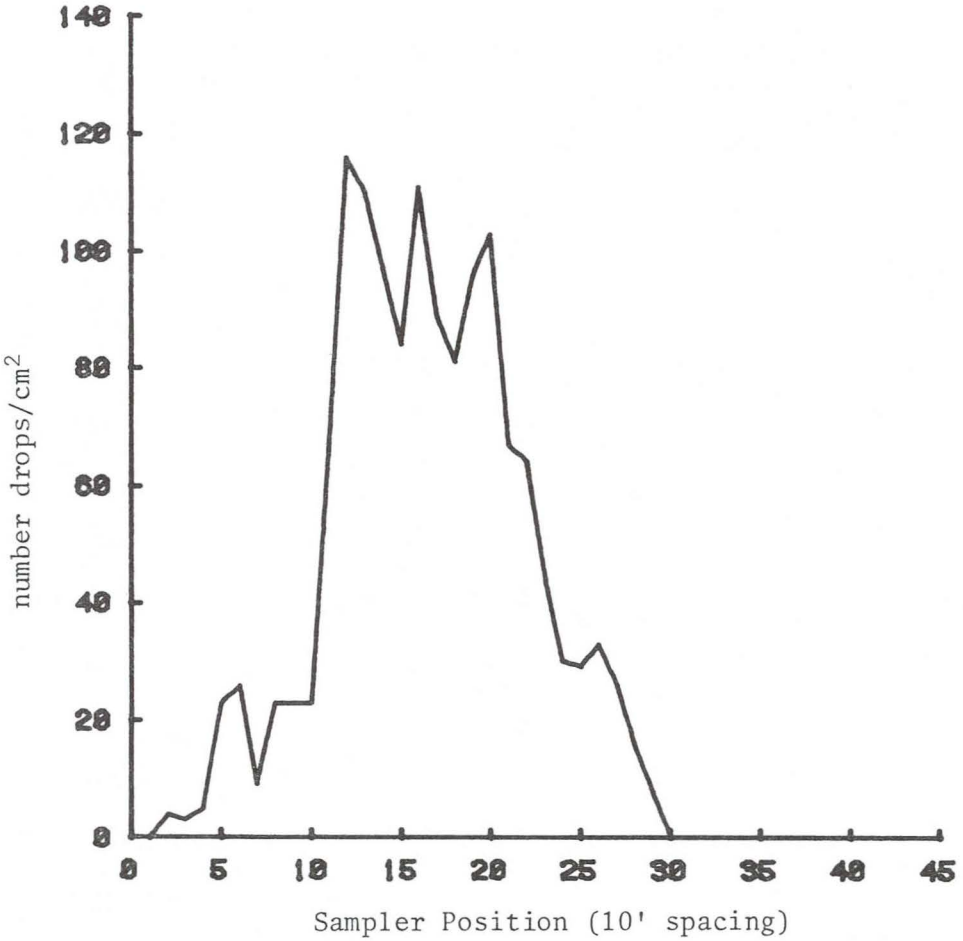

Figure 15. Trial 9, Thuricide 16B, droplet density recovered along sampling line perpendicular to spray release line.

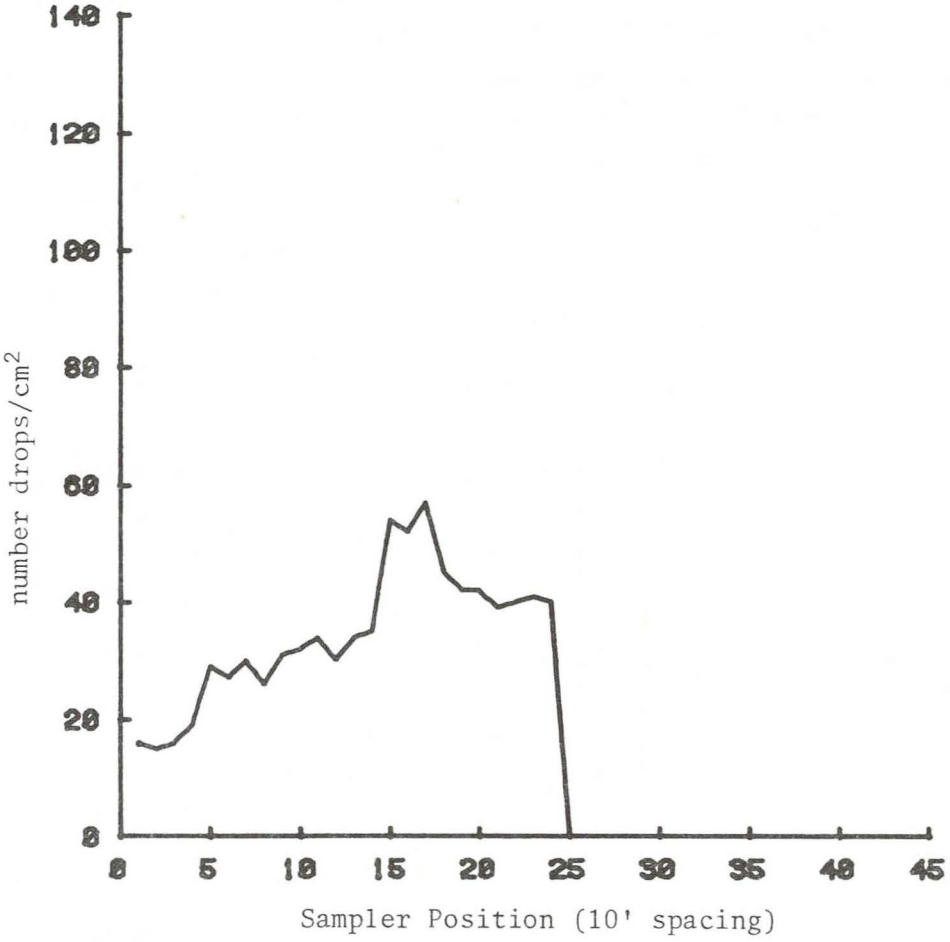

Figure 16. Trial 11, Sevin 4-oil, droplet density recovered along sampling line.

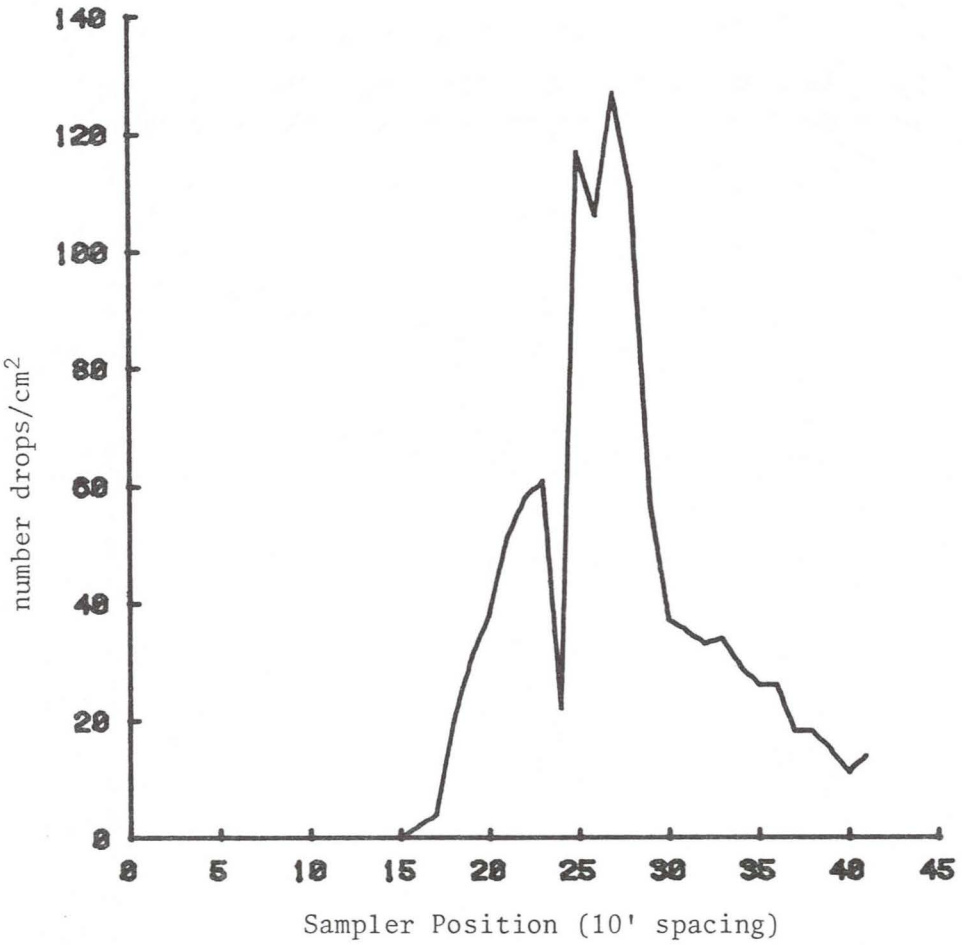

Figure 17. Trial 12, Sevin 4-oil, droplet density recovered along sampling line.

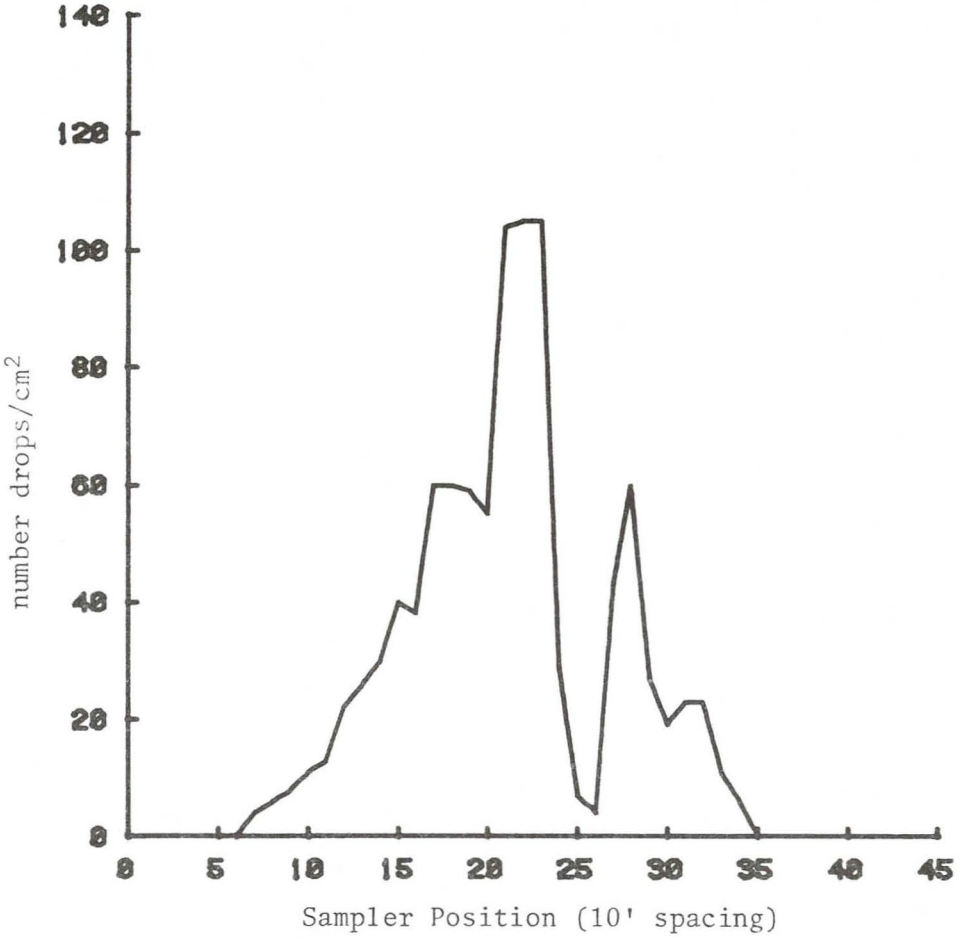

Figure 18. Trial 13, Sevin 4-oil, droplet density recovered along sampling line.

CONCLUSIONS

The Marsh Turbo Thrush provided a spray pattern and spray characteristics suitable for application of insecticides to forests. The higher speed of the Marsh Turbo Thrush provides energy for a high degree of atomization. Likewise, the swath width was wider than is usually observed from other small agricultural aircraft. It must be recognized that as atomization increases (more droplet break up), less volume will be deposited on the ground. This observation is reflected in these data. As the drop size increases more drops settle to the ground, providing for a higher accountancy of the total material applied. Data are needed to better understand the vertical and spacial distribution of spray droplets in the target area in terms of predicting the ultimate fate of the spray. This type of data would permit recommendations of more specific VMD's for particular applications, considering all the variables of insecticide, target insect, environment, forest type, meteorology, aircraft, etc.

The Marsh Turbo Thrush should be demonstrated in complex mountainous terrain on a pilot project basis against a forest defoliator. Planning and conduct of the test should use spray dispersion prediction modeling methods both for spray accountancy and selection of optimum spray strategy.

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